Mini-Review on Technology in Safety Training Delivery

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Abstract. The construction site is in a constant state of fluidity. This constant change presents challenges for construction players who must be able to foresee hazardous conditions before they cause injuries or fatalities on the construction site. Nowadays, technology continuously improves the way the construction industry works. In line with the industrial revolution, technology evolution will improve the effectiveness of construction industry operation. Embracing technologies would benefits inefficiencies, diminishing cost and improve health and safety levels. Therefore, this paper sought to review the technologies that can be implemented in training delivery, especially for safety training. A systematic literature review has been conducted to determine suitable technology in assisting safety training. Based on the deductive content analysis, there are three types of technologies that can be used as an approach in training delivery. The findings of the study prevail which technology particularly will create digitally. It seems that this application of technology can provide a better approach to assess potential problems such as risks on the construction site. These technologies can be adapted to become a training module in order to enhance the productivity and minimise the occurrence of accidents in Malaysia construction industry.

1. Introduction

In line with the revolution of industry, technology continuously evolvements the way the construction industry works. The nature of construction activities which constant change presents diverse challenges for safety managers. According to Gheisari, Irizarry, & Walker, (2014) one of the duties of care for safety managers is must be able to foresee, as much as possible hazardous conditions before they cause injuries or fatalities on the job site. Hence, the improvement of technology and the developments in information and technology show potential in reducing risk and protecting workers from getting injured and harm. Carson & Harder, (2016), in his study, stated that by embracing technologies would benefits inefficiencies, diminishing cost and improve health and safety levels. This statement, later supported by (Gasevic, Mirriahi, Dawson, & Joksimovic, 2017), he points out that technology particularly creating digital models, would providing a better approach to assess potential problems such as risks on the activities on site. Rico, Ramírez, Riofrío-Luzcando, & Berrocal-Lobo, (2017)in his study shows that technology can help in establishing a more meticulous underwriting style and pricing, customized to client's operations. This outcome proved that constant technology development could influence the way the construction industry operates. These

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construction technologies were used which advantageous in all construction processes covering from preconstruction until post-construction stages.

2. Technology in Training Delivery

According to Goetsch (1993), one of the fundamental principles of learning is "learning by doing", emphasising on adequate hands-on learning opportunities for learners. As a result, some researchers have explored other methods to improve the delivery the safety training especially on the use of technology to create safety training modules (C.-L. Ho & Dzeng, 2010; Mohd, Ali, Ebrahimi, & Azizi, 2019);. By using technology, training has become more flexible in terms of time management, cost, and experience (Polymeropoulou, 2014). Many researchers have explored the benefit of technology in training delivery. Table 1 shows the technologies in training delivery. Based on this, the discussion onward will be categorised into virtual reality (VR), augmented reality (AR) and game

Table 1. Technology in delivery training.

Author/year	Industry	Technology	Focus
(Xie, Tudoreanu, & Shi, 2006)	Construction	Virtual Reality	Hazard Identification at structure buildings.
(Xie, Carr, Shi, & Issa, 2010)	Construction	Virtual Reality	Construction Site Environment
(Hadipriono & Fabian, 1996)	Construction	Virtual Reality	Hazard Identification Training
(Tichon & Driver, 2010)	Construction	Augmented Reality	Plant Operator Training
(Duffy, 2003)	Manufacturing	Virtual Reality	Hazard Identification Training
(Bryan, 2011)	Logging	Virtual Reality	Hazard Identification
(Kizil & J. Joy, 2001)	Mining	Virtual Reality	Simulation of mining workplace – hazard identification
(Lincoln, Lucas, McKibbin, Woodward, & Bevan, 2008)	Mining	VR + AR	Plant simulation - Conveyor
(Tichon & Burgess-Limerick, 2011)	Mining	Game software	Hazard Identification
(Isler & Isler, 2011)	Driving	Game	Simulation for driving
(Tivesten & Dozza, 2015)	Driving	Game	Simulation for driving
(Bryan, 2011)	Logging	Virtual Reality	Hazard Identification

2.1.1. Virtual Reality

Virtual Reality (VR) is not a computer, but the technology that uses computers as a basis for creating reality, which is an entirely artificial digital environment that uses computer hardware and software to create the appearance of a real environment to the user using unique gadgets i.e. goggles, gloves, earphones and etc. (Kipper & Rampolla, 2014). It is a simulation which uses computer graphics to build or form such as actual situation (Piovesan, Passerino, & Pereira, 2012). Most of the VR system provides a visual experience that is created by using computer-aided design (CAD) or other graphics/animation system, but researchers use a device interface that will add sound and touch. The use of visual technology to help to teach and learning in education and training has resulted in

dramatic growth. Particularly in conventional education, demonstration and training skills, ranging from the introduction of colour images for video performance and followed by a presentation of computer graphic animation with the touch (Bricken, 1990; Guo, Yu, & Skitmore, 2017; Salas, Wildman, & Piccolo, 2009)

VR technological progress has ultimately benefited the education field and training through simulator developments that are grounded in VR technology. VR is characterised by three basic ideas which are immersion, interaction and involvement (Salas et al., 2009). VR technology offers an immersion experience; the user will have the real sensation of being inside the virtual world of the computer (Mayrose, 2012) by using devices, i.e. digital helmets, digital cave, digital gloves and etc. Moreover, the user can involve in exploring a virtual environment. It is as if the users take part of the virtual world and they can interfere directly in the result of the application, the user can navigate the virtual environment in a passive or active way (Hadipriono & Fabian, 1996; Janice Rickards, 2000) However, VR requires some high-end hardware and software to be developed (Ebersole, 1997), hence makes it unaffordable (Alhalabi, 1999).

2.1.2. Augmented Reality

Augmented Reality (AR) in general is a first-person experience. It is a combination of real-world and computer-generated data from a user's perspective (Azuma, 1997; Shirazi, 2014; Yilmaz, 2016). Unlike VR, where the user is provided with a completely natural experience in a realistically simulated world, the goal of Augmented Reality is to give experience in the real world, with virtual objects superimposed upon or composited with the real world (Kipper & Rampolla, 2014). Therefore, AR technology supplements reality, rather than completely replacing it. AR becomes the "middle ground" between the completely synthetic and the authentic (Lee, 2012).

AR technology is currently applied in numerous industry such as medical maintenance, scientific visualisation, maintenance, cultural heritage and military application (Cawood & Fiala, 2008); (Gimeno, Morillo, Casas, & Fernandez, 2012). In education, AR technology gives the ability for students to manipulate virtual objects or representations of real objects that would otherwise be impossible to hold as well as learn tasks and skills (Kesim & Ozarslan, 2012). However, there are challenges that need to overcome; people may not want to rely on their cell phones, which have small screens on which to superimpose information (Coimbra, Cardoso, & Mateus, 2015). Besides, these technologies also depend on devices such as network camera, Wi-Fi router, watertight box and much more (Merhi, 2016).

2.1.3. Game

Game can be defined as "*an artificially constructed, competitive activity with a specific goal, a set of rules and constraints that are located in specific contact"* (McGlarty et al., 2012; Merhi, 2016). This means that game is not a reality and is constructed with activities that resemble the reality. On top of that, game can provide a competitive environment for players to achieve his or her goal. Games can be divided into two types which are commercial games and educational games. Commercial games tend to be more complex because it is more immersive and focus more on strategy and decision making (Prensky, 2005; Yang, Chien, & Liu, 2012) Meanwhile for education game is more uncomplicated and straightforward, sometimes players can achieve him or her target by memorising the pattern of the game (Heintz & Law, 2015).

Education game has been practised in classroom education since the 1970s based on learning theorist. This approach is known as edutainment and was inspired by behaviourism, cognitivism and socio-cultural theory (Carvalho, 2017). It tries to focus on the straightforward delivery method of information using computer games. There are a lot of games that have been developed in educating students in various subjects such as math, science, language, geography, health, social study, and history and these games are developed in many types of genre such as action, strategy, puzzle, simulation, and adventure (Mohd, Ali, Bandi, & Ismail, 2019). The effectiveness of educational games have been proved by the researcher; they found that the student's motivation increase by

playing games (Blunt, 2007; Kim & Watson, 2017). Besides that, research has been done by Hackett & Betz, (1981) on a group of class freshmen students in an engineering technology course. The result shows that most students preferred the game simulator, the computer game was less hard than reading and they tend to discuss with friends and easy to understand the learning (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012; Mayer, 2005).

Conversely, the commercial game is more severe than an education game. The focus of this game is to train players in planning strategy and decision making (Ryan, Hill, & Mcgrath, 2000). This type of games has been widely using, especially in military training (K. Ho, Tang, Dawal, & Olugu, 2018). Military use simulation of war game to train US Army about the battle staff and war environment (Macedonia, 2002). Hence this type of games was created and played for some purposes. If the purpose of the game for operational use, the purpose will be to develop some understanding of the way in which purposeful behaviour can impact on the situation that occurs in the game. These situations will model real situations, which individual be able to choose or decided for a better chance to acquire new or different resources (Fallis, 2013). This game is also known as an operational game. It is a sophisticated game and will train players in term of planning; strategy, testing, and exploration begin (Crookall, 2010). This type of games is suitable to use as a module to train players to identify hazard on a construction site. Furthermore, by using the game approach as a training method will allow the participants to make mistakes and learns from those mistakes in a realistic environment and also will not harm the participant as they would in real life (Ncube, 2009).

The game approach gave advantages which have been proven in terms of cost and retention of knowledge compared to conventional classroom teaching (Kirriemuir & McFarlane, 2004). This is because by actively participating in the learning process, learners take charge of their own learning by observing and "doing". Learners are more likely to retain knowledge by at least 30%, and the percentage may even reach 90% (Goetsch, 1993). Gaming is an approach that applies technology to provide a near-real experience with interactive field training, and also supporting the theory of learning by doing with real case scenario (Mohd, Ali, Bandi, et al., 2019). For example, in New Zealand, the transportation department used affordable technology to develop a simulation of driving to measure the awareness and decision making among those new drivers in identifying hazards (Mohd, Ali, Bandi, et al., 2019).

In Ireland, a simulation game known as MERIT (abbreviated from Management, Enterprise, Risk, Innovation and Teamwork), initially developed by Loughborough University in the UK, was integrated into the blended learning module to accommodate the needs for Continuing Professional Development (CPD) among construction professionals ((Wall & Ahmed, 2008). In Malaysia, Virtual Simulated Traffics for Road Safety Education (ViSTREET) has been designed by three researchers from Universiti Malaysia Sarawak for use in teaching and learning off-road safety curriculum to schoolchildren aged 12 to (H. R. Chen, Hwang, Wu, Huang, & Hsueh, 2011). However, safety training in construction within the Malaysian context has yet to adopt into a game training module.

3. Comparison Of Technology In Training Delivery

Advanced technology such as Virtual Reality (VR) requires some high-end hardware and software which can be costly and limited to researchers who have access to this technology because of the availability of funding for their research (C. J. Chen, 2006). This method is by far the most satisfactory to the student but might be unaffordable (Alhalabi, 1999). As highlighted by Filigenzi et al. (2000), there is a need for affordable technology. Affordable technology is a technology that can be developed using a simple software but is able to give the same experience offered by other more advanced and expensive applications such as web-based training, learning via CD-ROM and games (Dickey, 2006; McGlarty et al., 2012) With this approach, hazard training becomes more flexible in term of time, cost and health.

Hence, in order to distinguish which each type of technology, a comparison using eight main attributes have been conducted. Training for hazard identification needs to be done using the hands-on module. It is because they need to experience themselves the scenario of handling the hazard so that

they can react according to the need of the hazard. However, hazard itself is harmful. Therefore, to train using hands-on seem to be impossible in real life because it will harm the individual. The gaming approach offers visual training with a digital world based scenario, which offers an immersive learning environment. Besides, it will encourage interaction and involvement of learner, where the individual will be able to practice and applied their knowledge without worry to get harm. Moreover, gaming approach does not require high-end hardware. It can be developed using affordable software which more cost-effective (Rico et al., 2017).Table 2 shows the summary of comparison for technology in training delivery.

Table 2. Comparison of technology in training delivery.

	Virtual Reality (VR)	Augmented Reality (AR)	Game
Immersive	•	•	•
Interaction	•	•	•
Involvement	•	•	•
Costly	•	•	-
Digital world	•	•	•
Real-world	-	•	-
Flexibility	•	•	•
Hands-on	•	•	•

4. Conclusion

The discussion above highlights the applications of technology has made a significant impact in delivering safety training in other industries. Although technology provides a safer approach to training delivery, some technologies require the high cost to develop, let alone operate them. In contrast, applying gaming approach in developing training modules involves the use of affordable technologies. Game criteria offer an interactive approach to a safer environment in the delivery of hazard identification training.

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